

March 7, 1878.

F. A. ABEL, C.B., Vice-President, in the Chair.

The Presents received were laid on the table and thanks ordered for them.

In pursuance of the Statutes, the names of the Candidates for election into the Society were read, as follows :—

Henry James Alderson, Lieut.-Col. R.A.	William Galloway.
Thomas Clifford Allbutt, M.A., M.D.	Henry Haversham Godwin-Austen, Major.
John Attfield, Ph.D., F.C.S.	Rev. William Greenwell, M.A., F.S.A.
John Gilbert Baker, F.L.S.	John Caulfield Hennyngton, Major-General.
Francis Maitland Balfour, F.L.S.	Thomas Hawksley, M.I.C.E.
Prof. Robert Bentley, F.L.S.	John Deakin Heaton, M.D.
Henry Bessemer, Assoc. Inst. C.E.	John Hopkinson, M.A., D.Sc.
Rev. Thomas George Bonney, M.A.	John Hughlings Jackson, M.D., F.R.C.P.
George Stewardson Brady, M.D., F.L.S.	Henry M. Jeffery, M.A.
John Syer Bristowe, M.D., F.R.C.P.	Lord Lindsay, M.P., P.R.A.S.
George Buchanan, M.A., M.D.	Richard Henry Major, Sec. R.G.S.
Walter Lawry Buller, Sc.D., F.L.S.	William Donald Napier, M.R.C.S.
Verney Lovett Cameron, Commander R.N., C.B.	Prof. Henry Alleyne Nicholson, M.D., Ph.D., D.Sc.
William Chimmo, Capt. R.N.	Richard Norris, M.D.
Cuthbert Collingwood, M.A., M.B., F.L.S.	Charles Henry Owen, Col. R.A.
Prof. James Henry Cotterill, M.A.	Thomas Bevill Peacock, M.D., F.R.C.P.
George Howard Darwin, M.A.	William Overend Priestley, M.D., F.R.C.P.
John Dixon, C.E.	Charles Bland Radcliffe, M.D., F.R.C.P.
James Matthews Duncan, A.M., M.D.	George Banks Rennie, C.E.
Sir Walter Elliot, K.C.S.I.	Samuel Roberts, M.A.
Francis Stephen Bennet François de Chaumont, M.D.	George F. Rodwell, F.R.A.S. F.C.S.
	George John Romanes, M.A.

Edward A. Schäfer, M.R.C.S.
 Arthur Schuster, Ph.D., F.R.A.S.
 Michael Scott, M. Inst. C.E.
 Prof. Harry Govier Seeley, F.L.S.
 Samuel Sharp, F.G.S., F.S.A.
 John Spiller, F.C.S.
 Hermann Sprengel, Ph.D.

George James Symons, Sec., M.S.
 Sir Henry Thompson, F.R.C.S.
 Charles S. Tomes, M.A.
 Edwin T. Truman, M.R.C.S.
 Benjamin Williamson, M.A.
 Prof. Edward Percival Wright,
 M.A., M.D.

The following Papers were read :—

- I. "On the Photometry of the Magneto-Electric Light." By
 Captain W. de W. ABNEY, R.E., F.R.S. Received February
 5, 1878.

At intervals during the last three years it has been my duty to ascertain the value of the illuminating power of different sources of light, which have been brought before Government for military purposes. As there is nothing secret in the results obtained, it seemed to me that I might communicate them to the Royal Society, I have obtained permission so to do.

There are certain difficulties to be overcome which affect the measurements, as it will be evident that the question of colour enters largely into them, which are not so great when lights produced by comparatively low temperatures are in question.

My first attempt to obtain a comparison of the value of any two lights was made by the method of extinction, that is, by introducing between the light and the eye a screen graduated in opacity. After comparing this method with that which I have recently adopted, I am not inclined to quarrel with it. Originally I employed a wedge of green-black glass for the screen, but owing to a complication in the results due to different coefficients of absorption for different parts of the spectrum, I had resort to strips of photographically graduated glass, the necessary black colour being obtained by toning with a platinum salt, and a consequent deposition of platinum black. With a couple of these slips back to back, and with the ends showing the greatest opacity placed together, a graduation was obtained varying between nearly total transparency and an opacity sufficient to cut off the direct rays of the strongest sunlight even when the eye was in its most sensitive condition. These strips being cemented together, and the relative opacity of every division of a small scale having been ascertained, they were caused to pass in front of a narrow slit which was open to the light to be tested. When all trace of light had disappeared readings were taken, and from the series the value of the light calculated. The great defect in this method is the variation in the sensitiveness of the eye, and when employing it, it is necessary to

be excessively cautious to take the readings under precisely similar circumstances, and also to check them from time to time by the extinction of some standard light. Thus I found that the maximum sensitiveness of the eye was practically attained after it had been excluded from the light for two minutes. Readings taken before that interval had elapsed were invariably too high, while afterwards they were fairly equable.

The annexed series shows this result. The readings were commenced after exposure of the eye to an ordinary reading lamp, and continued for more than ten minutes.

3·16	at the commencement.		
3·28	at the end of $\frac{1}{2}$	minute's darkness.	
3·38	at the end of $1\frac{1}{2}$	„	„
3·42	at the end of $2\frac{1}{2}$	„	„
3·48	at the end of 3	„	„
3·45	at the end of 5	„	„
3·48	at the end of 10	„	„

A similar form of instrument was made for Sir Charles Wheatstone without his knowledge of the existence of mine; but I am unaware of the results he obtained.

In the diagrams which accompany this paper I have given the curve of intensity of the magneto-electric light generated by a machine, similar to that to which reference will subsequently be made, and it will be noticed how close is the agreement between it and the curve which indicates the intensity of the blue light.

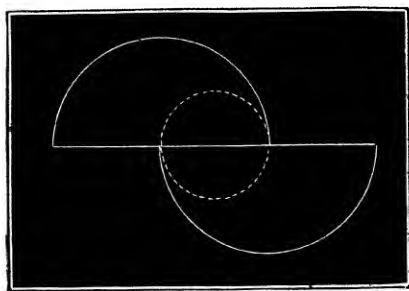
Later it was my endeavour to compare the values of the different coloured components radiated from any source of light, and my original apparatus consisted of a double spectroscopic arrangement by which the lights from the two sources entered by different slits into the spectroscope, and to the eye the spectra appeared vertically one over the other. After screening off all of the two spectra except a narrow strip, and by applying a telescope with a divided lens, as will shortly be described, the intensities of the two strips were equalised by widening or narrowing one or other of the slits. The ratio of the widths of the slits gave approximately the values of the different intensities of the light in the particular part of the spectrum. For light giving a continuous spectrum this method answered admirably, and I believe it was on the same principle that Lord Rayleigh measured the relative values of sky and sunlight; but for lights whose spectra were discontinuous the method failed owing to the labour it involved. This method was then abandoned, and another was sought which should integrate two or three parts of the visible spectrum.

In my hands Bunsen's method of photometry has always been uncertain, perhaps through some personal obliquity, though I believe that

with other persons the same uncertainty has been observed. Rumford's method has never been a favourite, but I believe that if the following modification of it be adopted, there can never be much difficulty in comparing lights of similar colours. The problem which I set myself was to obtain shadows of equal size, and to place them side by side as seen by the eye. The following plan accomplishes this:—

In an opaque screen of some half metre square two equal slits of about half a centimetre in width and 7.5 centimetres in length were cut parallel to one another, the lengths being vertical. These slits were separated by 7.2 centimetres, and were covered with a diaphanous screen, white tissue paper being apparently the best substance to employ, though ground glass was also tried. The tissue paper was placed at a small distance from the opaque screen, so that the texture was invisible when the borders of the slit were sharp when viewed by an observing telescope. A rod of a centimetre in diameter was placed in front of the tissue screen, and so arranged that the shadows thrown by the two sources of light entirely covered the slits. The movable light was caused to travel along a scale fixed at such an angle as to ensure this always occurring. The necessary precautions were taken to ensure that the shadows falling on the screen were at equal distances from the centre of the rod.

In order to cause the two shadows thus thrown to approach each other, a divided lens of about 16 centimetres focus was made to form the objective of a telescope, and by carefully separating the optical centres of the two halves (see figure) when the line of division was



kept in a horizontal position, the images of the two slits could be caused to approach one another, and could be viewed in the same field by an eyepiece. By turning the telescope in its Y's the same result could be obtained, though in this case the image seen of the one slit would be formed by the opposite half of the lens to that which formed it in the first observation. Measurements were taken with standard lights, till the adjustment was found which gave equal illumination of both sides of the lens. When the opaque screen, the telescope, and the head of the observer were carefully shielded from all extraneous light, the

observations are singularly accordant. The following observations made with a standard candle and a paraffin lamp, the light traversing a red medium, will give an idea of the correctness of the results:—

Readings of the Lamp in Candle Power.

	10·25
	10·23
	10·18
	10·23
	10·26
	10·23
Mean	10·23

If there be any drawback to this method, it is that an assistant is required to alter the distances of the movable light.

I may also remark that there are shades of light between which it is sometimes difficult to judge. If too bright the requisite diminution can be obtained by using diaphragms in the telescope, and by altering the magnifying power of the eye-piece. If too dark, an addition to the light which reaches the slits may be given by giving them an equal amount of illumination from an independent source.

To secure the separation of the different portions of the spectrum, resort was had to absorbing media. After many trials I came to the conclusion that nothing seemed preferable to red glass, which absorbed practically every part of the spectrum except the red end, and an ammoniacal solution of copper sulphate. These two absorbing media were employed in the experiments which I am about to describe; very little of spectrum is left unaccounted for, and the results obtained are sufficiently striking to record.

A red glass was obtained which had sufficiently plane surfaces, and a cell with parallel sides was used for holding the copper solution. The absorbing media were placed between the rod and the opaque screen, and absolutely parallel with the latter.

The following is an outline of the experiments to which the attention is to be drawn. The primary object was to ascertain the relation between the horse-power expended, the light produced, and the number of revolutions of the armature. The machine employed was of the Gramme form, and weighed somewhere about 17 cwt. It had three pairs of vertical coils, one of which was used for magnetization. To work it, what is known as the steam sapper was employed. This is a road locomotive from the shops of Aveling and Porter, of Rochester, and is adapted to driving machinery by applying a band to the fly-wheel. It works fairly steadily when not overtaxed. An indicator was attached for taking diagrams from which to calculate the horse-power expended. The number of revolutions of the armature was

taken by a velocimeter, and a large tangent galvanometer was inserted in the circuit, the diameter of the arc being 33 times that of the needle. An automatically working electric lamp having perfectly dry square carbons of $\frac{1}{2}$ inch side was the source of light, and was placed at fixed distances of 75, 150, or 50 feet from the measuring apparatus as circumstances required. It gave a steady light when the engine worked regularly, and the brilliancy of the light was not increased by altering the distance apart of the carbons. When a series of readings was to be taken, the horse-power expended in driving the machine with the collecting brushes up was found, and then the brushes turned down, and the light allowed to burn for ten minutes before any measurement was taken. The number of revolutions of the armature was then approximately ascertained, and a diagram taken when the velocimeter was applied to the machine. The readings of the galvanometer were recorded by an assistant working under my colleague, Captain Armstrong, R.E., and then measurements of the illuminating power taken by myself and checked by an intelligent assistant. The light transmitted through the red medium was first measured, and then through the blue. If the first and last of the readings compared favourably with each other, the series was taken as worthy of confidence. If, on the other hand, great fluctuations were observed, which was sometimes the case owing to the occasional irregularities of the motive power, and to impurities in the carbons themselves, a fresh set of readings was taken. As often as possible readings were taken through the blue and red media at the same number of revolutions per minute of the armature. This was not always practicable, or even necessary. This will explain the reason of the variable revolutions recorded in the tables. I may remark that the revolutions were always taken at the commencement and end of each set of readings, and if these were tolerably close the mean was taken as the correct value for the mean of the readings. With any great variation, say of more than ten revolutions, the readings were rejected altogether. It was found difficult to make a comparison with a standard or pair of standard candles, owing to the small distance from the screen they sometimes occupied; hence an intermediate light from a paraffin lamp was made use of, which before and after each series of readings was compared with the standard candle. The variation of the lamp light was very small, ranging from 10·23 to 10·05. The light from the electric lamp was admitted into the observing-room through an aperture in the wall of about 18 inches square, and great care was taken that any reflected light was cut off the screen.

In addition to the optical readings, an endeavour was made to secure a record of the actinic value of light. Paper sensitized with silver chloride was exposed to the light at a distance of three feet from the carbon points, one strip was placed behind a cell filled with

quinine sulphate, whilst another was exposed to the full action of the unshaded light. The times of exposure varied between one and ten minutes. The intensity of the actinism was measured by Roscoe's method, which need not be described. The curve obtained from the paper exposed behind the quinine cell is practically identical with that obtained optically from the blue components when any one point in the former curve is made to correspond to a point in the latter which has the same abscissa. The following Table gives the results of the experiments made with this particular machine. The numbers or letters in the first column refer to the numbers in the diagram. The horse-power given is the total horse-power recorded less that required to drive the machine with the brushes up.

Expenditure of H.P.

Table I refers to Diagram I.

No.	Revolutions.	H.P.
<i>a</i>	240	1·0
<i>b</i>	308	1·6
<i>c</i>	350	2·5
<i>d</i>	400	3·8
<i>e</i>	460	5·6
<i>f</i>	480	5·7
<i>g</i>	520	7·9
<i>h</i>	550	8·5
<i>k</i>	565	9·0

Integration of Blue Light.

Table II refers to Diagram II.

No.	Revolutions.	Candles.
1...	240	360
2...	308	660
3...	350	750
4...	425	1,700
5...	460	2,500
6...	490	3,000
7...	520	4,860
8...	550	4,800
9...	565	6,500
10...	580	6,000
11...	600 ?*	10,100

Integration of Red Light.

Table III refers to Diagram II.

No.	Revolutions.	Candles.
12...	240	180
13...	308	280
14...	460	860
15...	500	1,080
16...	520	1,300
17...	540	1,620
18...	575	1,520
19...	580	2,100
20...	600 ?	2,400

Integration of Actinic Power.

Table IV refers to Diagram II.

No.	Revolutions.	Candles.
21...	350	890
22...	460	2,750
23...	560	9,000
24...	580	10,050
25...	600 ?	11,020

* A ? is placed against the 600 revolutions, as the engine at that velocity worked somewhat unequally.

Currents. Machine No. I.

Table V refers to Diagram IV.

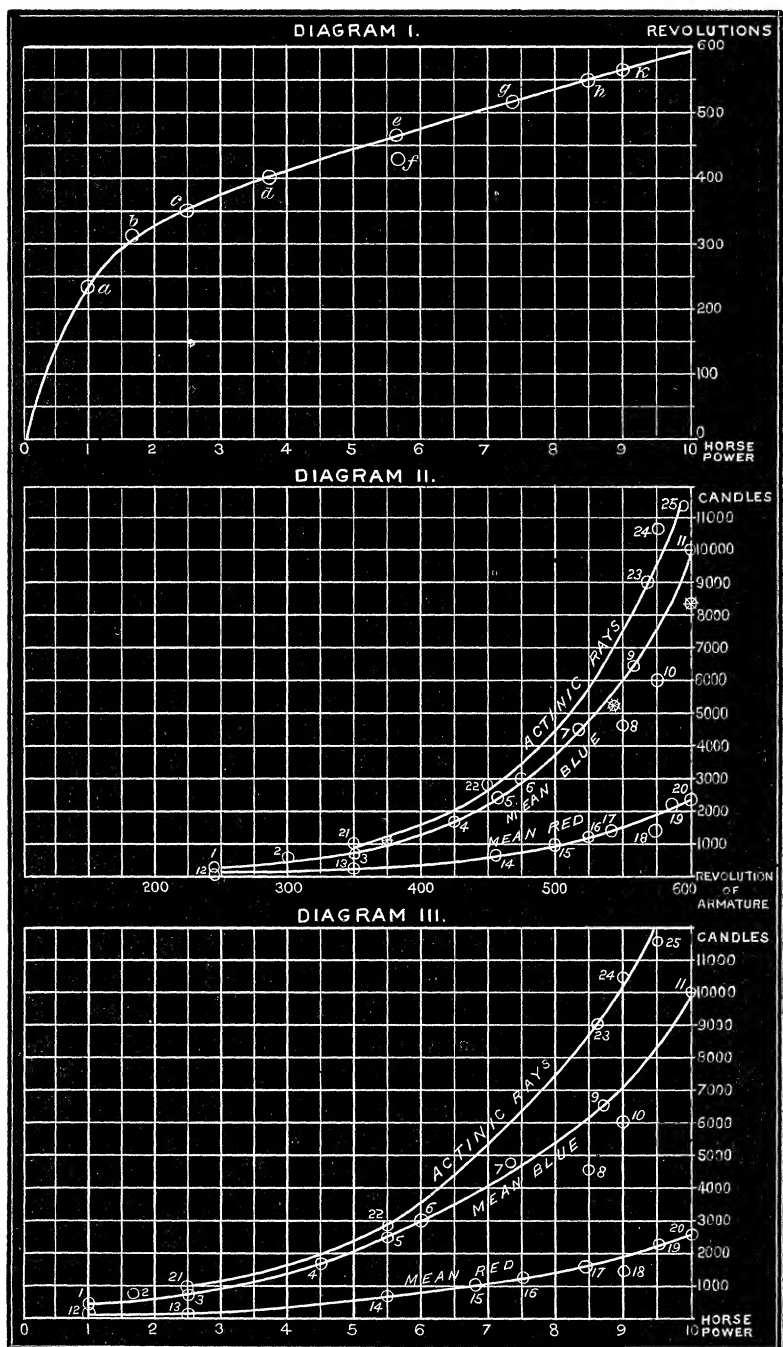
No.	Revolutions.	Tangents.	Remarks.
26.....	300	1·15	1st set of experiments.
27.....	350	1·31	
28.....	460	1·80	
29.....	540	2·47	
30.....	240	·51	Experiments during which the illuminating power was measured. Tables II, III, and IV.
31.....	308	·90	
32.....	370	1·33	
33.....	425	1·48	
34.....	460	1·66	
35.....	500	1·96	
36.....	580	2·20	
37.....	600 ?	2·30	

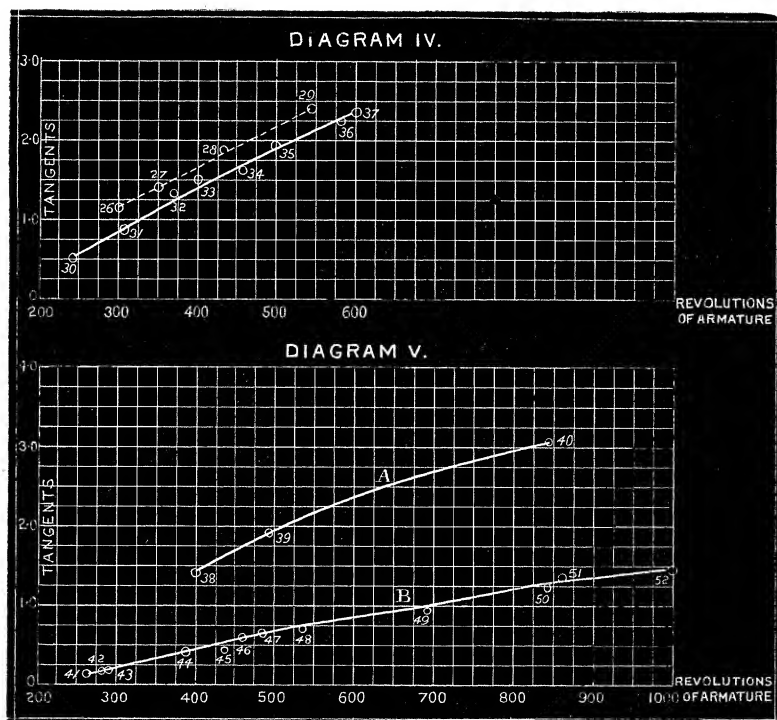
Currents. Machine No. II.

Table VI refers to Diagram V.

No.	Revolutions.	Tangents.	Remarks.
38.....	398	1·40	Curve B, fig. V. 1st set of experiments.
39.....	490	1·88	
40.....	846	3·08	
41.....	264	·10	
42.....	280	·12	2nd set of experiments. Curve A, fig. VI.
43.....	288	·17	
44.....	384	·38	
45.....	438	·48	
46.....	458	·53	
47.....	484	·56	
48.....	534	·67	
49.....	692	·92	
50.....	842	1·25	
51.....	862	1·33	
52.....	1,014	1·45	

In Diagram II the stars show the value of the light [from the method of extinction.





The following is a statement, furnished me by Captain R. Y. Armstrong, R.E., of the electrical conditions of the circuit.

The resistance of the stationary wire = 4.46 ohms.

„ „ magnetizing coil = 0.44 ohm.

In the generator the resistance of the light-circuit coil = 0.24 ohm.

The light coils were in divided circuit, as were also the right and left stationary coils.

When driven at from 375 to 383 revolutions, the resistance of the voltaic arc was about 0.18 ohm; the other resistances in the circuit were 0.7 ohm. The electromotive force of the machine when driven at the above speed was 111 volts, a measure which has been arrived at by Captain Armstrong from other experiments. The electromotive force between 375 and 383 revolutions of the armature was assumed to vary as the number of revolutions, an assumption which was borne out as practically correct by other measurements made for the purpose. In order to ascertain what effect the insertion of resistance had on the current, the following experiment was undertaken by Captain Armstrong with a smaller form of gramme machine, called Machine No. II.

Two resistances were inserted in the circuit for two different sets of readings, in the first case 1.1 ohm of total resistance, in the other 2.72.

Table VI refers to these experiments, the curve marked A in the Diagram V being that due to the first, B being that due to the second. It will be noticed that practically the curve becomes a straight line, or, in other words, the electromotive force increases directly as the number of revolutions of the armature, a result which might have been expected theoretically. It will also be seen that the current for any given number of revolutions varies inversely as the resistance in circuit, or, in other words, that the electromotive force for a given number of revolutions is constant.

In any results, therefore, which are given descriptive of the light produced by any machine, the following should be noted :—

Number of revolutions of armature ;
Resistance in circuit ;
Horse-power expended ;
Colour of light measured ;
Electromotive forces.

together with the size of the carbons employed, and other obvious details.

II. "Experimental Researches on the Temperature of the Head." By J. S. LOMBARD, M.D., formerly Assistant-Professor of Physiology in Harvard University, U.S. Communicated by H. CHARLTON BASTIAN, M.D., F.R.S., Professor of Pathological Anatomy in University College, London.

(Abstract.)

The present communication forms an abstract of the first portion of a series of investigations having the following primary objects in view :—

1st. To find out, as far as possible, the normal relative temperatures of different portions of the surface of the head, when the brain is comparatively inactive.

2nd. To study the effect of different mental states upon the different portions of the surface of the head previously examined in the condition of comparative cerebral inactivity.

The *ultimate* objects were two-fold ; namely :—

1st. To furnish, if possible, some reliable data as a starting point,





1000



FIG. 10. Same as in Fig. 9, but for the 500-hPa geopotential height.

